ALASKA OREGON WASHINGTON
PACIFIC NORTH WEST FOREST AND RANGE EXPERIMENT STATION

USDA FOREST SERVICE RESEARCH NOTE

PNW-276 September 1976

ERRORS FROM APPLICATION OF WESTERN HEMLOCK SITE CURVES TO MOUNTAIN HEMLOCK

by

Francis R. Herman, *Mensurationist*

and

Jerry F. Franklin, *Chief Plant Ecologist*

ABSTRACT

Application of coastal western hemlock site curves to mature and overmature mountain hemlock stands may lead to large errors in estimation of growth and yield. Overestimation of site by 25 feet (7.6 m), for example, leads to volume estimation errors of 60 to 240 percent depending on volume tables and minimum diameters selected.

KEYWORDS: Site index -)stand height/age, volume estimation -)yield tables, mountain hemlock, *Tsuga mertensiana*, western hemlock, *Tsuga heterophylla*.

Forests dominated by mountain hemlock (*Tsuga mertensiana*) cover thousands of acres at high elevations in the Pacific Northwest. Nearly pure, apparently even-aged mountain hemlock stands are common in the high Cascades of southern Washington and central and southern Oregon (Franklin 1965) where they are often included in the commercial forest-land base. However, foresters charged with managing these lands are frustrated by an absence of data on which to base growth and yield predictions and prescribe silvicultural treatments. Neither site index curves nor yield tables are available for mountain hemlock.

Some land managers are using western hemlock (*Tsuga heterophylla*) site curves and yield tables (Barnes 1962) as interim guides to growth and yield of mountain hemlock. It is unlikely that those curves and tables accurately estimate productivity in either high-elevation western hemlock or in higher elevation mountain hemlock growing in the Cascade Range of Oregon and Washington. Barnes' tables are based entirely within the coastal fog-belt range of western hemlock. No Cascade stands were investigated.

Stem analysis data recently collected from 11 dominant and codominant mountain hemlocks provided us with the first detailed growth information for the species. Height growth patterns from those 11 mountain hemlocks were compared in this research with existing western hemlock site curves. The actual height of each of those trees at 100 years is compared with the height predicted from the western hemlock site curves based on total age and height. Although our sample is small, the large and consistent overestimation of site index that results from the use of the western hemlock site curves in old-growth mountain hemlock warrants this report.

METHODS

In the course of preparing site curves for noble fir (*Abies procera*) (DeMars et al. 1970), dominant and codominant specimens of associated trees occurring in the same plots were felled and sectioned. Eleven dominant and codominant mountain hemlocks were included from 10 different plots, mostly on the northern Mount Hood National Forest (table 1). The trees selected were the tallest sound, free-growing mountain hemlocks--free of visible defects, such as breaks or large forks. Field and laboratory stem analysis methods used are described in Herman and DeMars (1970) and Herman et al. (1975). Trees were felled and typically sectioned at breast height and at irregular intervals up the stem--every 8 to 10 feet (2.5 to 3.0 m) for small trees and 16 to 18 feet (5 to 5.5 m) for large trees. Disks from each section were brought into the laboratory for detailed ring analysis.

Graphs of height over age developed from stem analyses are the basic data for this report. Total height above ground and age at stump and breast height were determined directly. Total age was estimated by projecting the stump to breast height growth rate back to the ground line. Height at 100 years was read from the height-age graphs. Total age and height of the mountain hemlocks were used on the western hemlock site index alinement chart (Barnes 1962, p. 5) to obtain a predicted site index or height at 100 years.

Table 1--*Comparison of actual height of 11 mountain hemlocks with predicted height at 100 years using western hemlock site curves*

Plot location	National Forest	Elevation	Crown class[1/]	Age at b.h.	Total age[2/]	Total height	Height at 100 years	Predicted height at 100 years[3/]	Error in prediction
		- *Feet* -		- - - *Years* - - -		- - - - - - - *Feet* - - - - -			
Timberline	Mount Hood	4,348	Dom	232	237	112	64	92	+28
Hood River Meadows	Mount Hood	4,392	Dom	260	266	126	85	100	+15
Upper Pocket Creek	Mount Hood	4,595	CoD	221	240	86	52	70	+18
Lower Pocket Creek	Mount Hood	2,394	CoD	246	257	150	86	120	+34
Wahtum Lake	Mount Hood	4,303	Dom	191	201	79	48	66	+18
North Wilson	Mount Hood	4,663	CoD	235	241	101	67	84	+17
Milepost 64	Mount Hood	3,926	CoD	263	274	106	40	86	+46
			CoD	273	284	96	30	77	+47
Fawn Meadow	Mount Hood	4,522	CoD	189	212	121	66	100	+34
Wildcat Mountain #1	Willamette	4,700	CoD	192	206	102	65	86	+19
Wildcat Mountain #2	Willamette	4,680	CoD	203	207	101	65	84	+21
Average for 10 areas[4/]		4,452	--	224	235	108	63	88	+25

[1/] CoD = codominant and Dom = dominant.

[2/] Determined by projecting growth rate between breast height and stump height (actual ages determined at each location) back to average ground line. Actual total ages are probably somewhat greater.

[3/] Site index or height at 100 years from western hemlock site index alinement chart based on total height and age of trees (Barnes 1962).

[4/] Two trees at Milepost 64 averaged for single plot values.

RESULTS

Western hemlock site curves grossly overestimate site index or height at 100 years for these 11 mountain hemlocks (table 1). The average predicted height at 100 years is about 25 feet (7.6 m) or over one-third greater than the actual height. The 11 trees, which range in age from 201 to 284 years, have errors of +15 to +47 feet (4.6 to 14.1 m).

Typical height growth graphs for mountain hemlock and curves for western hemlock for site index 60 to 110 are shown in figure 1. The deviation between predicted and actual values for height at 100 years is clearly a consequence of slower height growth in youthful mountain hemlock coupled with prolonged growth into later life. This is similar to the height growth pattern observed in Douglas-fir at high elevations compared with lower elevations (Curtis et al. 1974).

None of the mountain hemlock exhibited any early suppression at stump height. Early growth was slow but steady in all cases. Trees at Milepost 64, which showed the greatest variance from the western hemlock site curves, provided an extreme example of an almost constant rate of height growth until they were felled at 263 years of age (fig. 1).

DISCUSSION AND CONCLUSIONS

Application of western hemlock site curves to mature and overmature mountain hemlock stands indicates unacceptable errors in estimation of growth and yield (table 2). The overestimation of site index by 25 feet (7.6 m) leads to errors at index age of 100 years; errors range from 60 to 85 percent in cubic-foot and 120 to 240 percent in board-foot volumes, depending on the minimum diameter used. This assumes, of course,

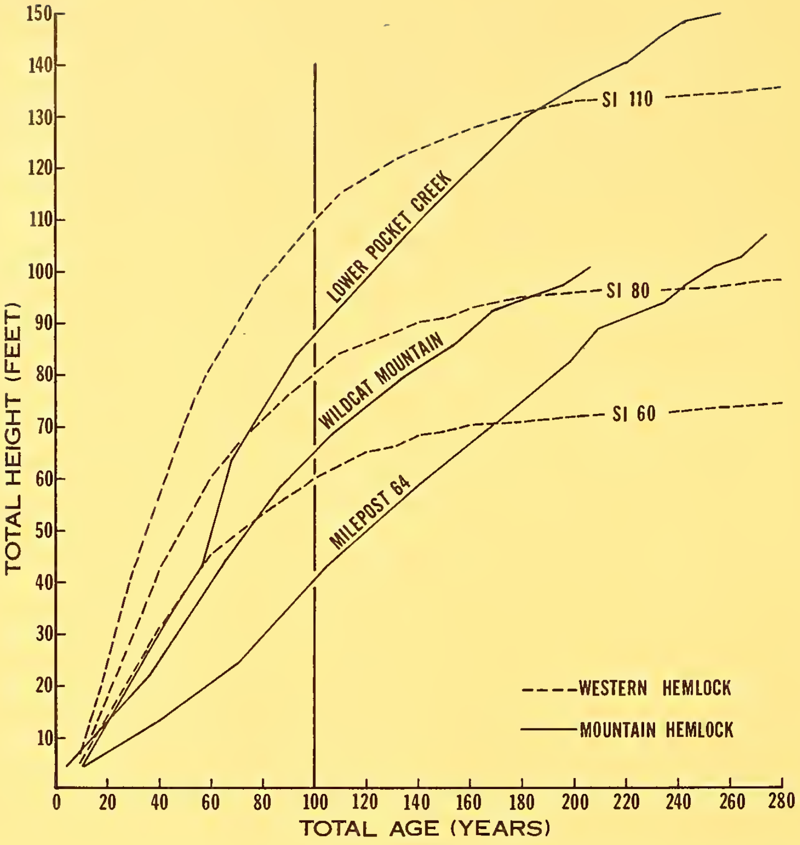

Figure 1.--Height-over-age curves for mountain hemlocks on three representative plots compared with Barnes' (1962) western hemlock site curves.

Table 2--*Comparison of estimated stand volumes per acre using actual height at 100 years and predicted height based on western hemlock site curves*[1/]

Item	Values based on		
	Actual height at 100 years	Predicted height at 100 years	Overestimation from western hemlock site index
			Percent
Height in feet (meters)	63 (19.2)	87 (26.5)	40
Western hemlock site class[2/]	VI	V	--
Volume per acre at 100 years[2/]			
Cubic feet in trees >1.5-inch d.b.h. (cubic meters)[3/]	6,310 (179)	9,990 (283)	58
Cubic feet in trees >6.5-inch d.b.h. (cubic meters)[3/]	4,968 (141)	9,130 (258)	84
Board feet, International 1/4-inch rule, in trees >6.5-inch d.b.h. [4/]	24,000	52,000	117
Board feet, International 1/4-inch rule, in trees >11.5-inch d.b.h. [4/]	10,000	34,000	240

1/ Site curves from Barnes (1962).

2/ From Barnes (1962). Estimated volumes interpolated from tables for British Columbia western hemlock because tables for Oregon and Washington do not include site classes V and VI.

3/ Converted to cubic meters from cubic feet.

4/ There is no single conversion to cubic meters from board feet.

that expected volumes in fully stocked mountain hemlock stands at 100 years are the same as for western hemlock stands of the same height.

Even with the correct western hemlock site index (height at 100 years), the western hemlock yield tables will not accurately estimate yields for mountain hemlock. For a given site index, growth and yield of young (<100 years old) mountain hemlock stands will almost certainly be less than in comparably aged coastal western hemlock stands because of slower growth rates and lower stocking levels. At 100 years, even if the mountain hemlock stand had stocking levels and average diameters similar to those in the western hemlock yield tables, a lower form factor for mountain hemlock might be expected to result in volumes below those shown in the western hemlock yield tables. Stem taper[1/] of mountain hemlock was consistently greater than that for western hemlock growing on comparable sites. Form quotient for the 11 mountain hemlocks averaged 64 and that for 10 comparable Cascade Range western hemlocks averaged 71.[2/]

The sustained growth of mountain hemlock could result in growth and stand volumes after 100 years which gradually surpass those shown in the western hemlock yield tables for a given site index or height at 100 years. Much of the volume often observed in old-growth mountain hemlock stands probably developed in the last half of their lives.

Deviations of mountain hemlock from western hemlock site curves may be even greater, on the average, than is indicated by our study trees. These trees are from sites relatively low in mountain hemlock's elevational range and from stands considered clearly "commercial." At higher elevations, particularly close to the upper limits of subalpine forest, early growth rates will be even slower.

Given the inapplicability of western hemlock site indices to mountain hemlock, what can the forester do to fill the present information gap? Obviously, whenever mountain hemlock is not a predominant stand component, he can utilize other species for which valid site index curves are available for estimating relative productive potential. When they are not available, the land manager can:

1. Develop local site curves and yield tables. Stem analyses will almost certainly be essential unless a good range of age classes on essentially identical sites is available for installation of temporary plots. Obtaining good ratio estimates of total age or years to breast height is critical because of the slow growth of mountain hemlock, especially near upper timberline.

[1/] Stem taper herein is defined as form quotient (the stem diameter inside bark at halfway point between ground and tree tip divided by diameter breast height inside bark).

[2/] The western and mountain hemlocks were from different plots but noble fir site index was essentially the same (81 and 80, respectively); elevation did differ--western hemlock plots averaged 3,500 feet (1 065 m) and mountain hemlock plots 4,450 (1 355 m).

2. If (1) is not possible, a crude adjustment of the western hemlock yield tables for mountain hemlock can be made by adjusting predicted site index downward, depending on the age of the stand. The reduction should be about 25 feet (7.6 m) for the predicted 100-year height for mountain hemlocks 200 to 300 years old. At least 10 years should be allowed for growth to breast height.

When final noble fir site curves are available, it may be possible to use the relationship between mountain hemlock and noble fir growth to estimate mountain hemlock site index. Estimates of productivity in mountain hemlock stands, and probably upper-slope western hemlock stands as well, will continue to be crude until appropriate site curves and yield tables can be developed.

LITERATURE CITED

Barnes, George H.
1962. Yield of even-aged stands of western hemlock. USDA For. Serv. Tech. Bull. 1273, 52 p.

Curtis, Robert O., Francis R. Herman, and Donald J. DeMars.
1974. Height growth and site index for Douglas-fir in high-elevation forests of the Oregon-Washington Cascades. For. Sci. 20(4): 307-316, illus.

DeMars, Donald J., Francis R. Herman, and John F. Bell.
1970. Preliminary site index curves for noble fir from stem analysis data. USDA For. Serv. Res. Note PNW-119, 9 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Franklin, Jerry F.
1965. Tentative ecological provinces within the true-fir hemlock forest areas of the Pacific Northwest. USDA For. Serv. Res. Pap. PNW-22, 31 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Herman, Francis R., and Donald J. DeMars.
1970. Techniques and problems of stem analysis of old-growth conifers in the Oregon-Washington Cascade Range. *In* Tree-ring analysis with special reference to northwest America. J. Harry G. Smith and John Worrall eds. Univ. B. C. Fac. For. Bull. 7, p. 74-77, illus.

Herman, Francis R., Donald J. DeMars, and Robert F. Woollard.
1975. Field and computer techniques for stem analysis of coniferous forest trees. USDA For. Serv. Res. Pap. PNW-194, 51 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

* * * * * * *

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Developing and evaluating alternative methods and levels of resource management.
3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research are made available promptly. Project headquarters are at:

Fairbanks, Alaska	Portland, Oregon
Juneau, Alaska	Olympia, Washington
Bend, Oregon	Seattle, Washington
Corvallis, Oregon	Wenatchee, Washington
La Grande, Oregon	

Mailing address: Pacific Northwest Forest and Range Experiment Station
P.O. Box 3141
Portland, Oregon 97208

GPO 997-074

The FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

The U.S. Department of Agriculture is an Equal Opportunity Employer. Applicants for all Department programs will be given equal consideration without regard to race, color, sex or national origin.